AUTOMATIC FILTER CHANGER FOR USE ON SURFACE MOUNTER INSPECTION CAMERA

This application is a continuation-in-part of prior co-pending application U.S. Serial No. 09/970,960, filed October 4, 2001.

TECHNICAL FIELD OF THE INVENTION

The invention relates to visualization of printed circuit boards and parts presenting characteristic visualization problems. The invention is particularly, but not exclusively, useful for recognizing by computer vision physical features of any of several types of printed circuit boards or electronic parts, where each type of board or part presents a different characteristic visualization problem.

BACKGROUND OF THE INVENTION

Automated printed circuit board assembly equipment, such as the Automated Component Mounter from Assembléon, utilize computer vision systems to inspect and accurately place printed circuit boards and parts to be mounted on those boards. The inspection of these items typically requires visualizing an item, recognizing the physical features of the item and analyzing the physical characteristics of the physical features.

An empty printed circuit board or card is typically picked out of a storage location and computer vision equipment, including a camera and frontal lighting, is employed by the assembly machine to inspect the physical features on the board. Certain of these physical features are called fiducials, which are provided to precisely register the parts that will be installed on the board. Other such physical features on the circuit board are solder paste contact pads. If the inspected board is not rejected, the assembly machine then places it into position to receive parts for mounting.

Each part to be mounted is then picked out of a storage location and computer vision equipment, again including a camera and frontal lighting, is employed by the assembly machine to inspect the part. If the part is not rejected, the assembly machine then steers the placement of the part with proper registration to its mounting position on the board or card.

Characteristic problems can arise, however, when the computer vision system attempts to inspect certain types of circuit boards, cards or parts. Some boards or cards are made of a light colored ceramic material and have gold or silver fiducials or solder paste contact pads.

These colors do not provide sufficient visual contrast for current computer vision systems to reliably recognize the fiducials or contact pads.

A similar problem is encountered with parts that have silver or gold metallic contacts on a white or light colored ceramic background, preventing the contacts from being reliably recognized.

Other parts have contacts of one color on a background of another color, which colors, when imaged by a monochrome camera, lack sufficient contrast to permit reliable recognition of the contacts.

Another characteristic problem encountered with certain types of parts is glare from the contacts and the background, again preventing reliable recognition of the contacts.

Yet another problem arises because the charge coupled device (CCD) cameras typically used in computer vision systems are extremely sensitive to infrared. As a result, images of parts that are especially reflective in the infrared spectrum are washed out and difficult to recognize reliably.

The predecessor of the present application teaches an inventive technique for recognizing the physical features of parts having metallic contacts on a light colored background. However, a printed circuit board assembly machine often must handle, in turn, a mixture of circuit boards and parts, each exhibiting a different one or more of the recognition problems described above. Currently, there are no techniques in use in printed circuit board assembly machines that overcome the variety of recognition problems thereby encountered.

SUMMARY OF THE INVENTION

In a printed circuit board assembly machine handling several types of circuit boards and parts, aspects of the invention may be found in a method and apparatus in which a filter is automatically deployed when inspecting circuit boards and parts of a certain type. The filter corrects characteristic problems encountered when visualizing the physical features of items of that type.

The contrast in a image between silver fiducials and a light colored printed circuit board, or between silver contacts and a light colored part, may be improved by linearly polarizing the illumination of the circuit board and imaging the board or part through a linear polarizing filter oriented in a different direction than the illumination filter.

The contrast between contacts of one color and a background of another color in an image of a part may be improved by imaging the part through a color filter.

The glare in an image of a circuit board or part may be reduced by imaging the board or part through a circular polarizing filter.

The effect of reflected infrared radiation on a CCD camera may be reduced in an image of a circuit board or part by imaging the board or part through a filter rejecting infrared.

More specifically, an aspect of the invention may be found in the following method for visualizing an item having physical features on a background. The item is illuminated with electromagnetic radiation, using an illumination source. An image is formed of the electromagnetic radiation reflected from the item, which image has characteristic defects depending on the type of

item being visualized. The reflected electromagnetic radiation is automatically filtered to remove the characteristic defects from the image, thereby improving the contrast between the physical features and the background in the filtered image.

The physical features of the circuit board or part may be recognized in the filtered image for the purpose of inspection.

Further aspect of the invention may be found in an apparatus for visualizing an item having physical features on a background. One or more sources illuminate the item with electromagnetic radiation. An image forming device forms an image of electromagnetic radiation reflected from the item, which image has a characteristic defect depending on the type of item being visualized. An actuator positions a filter such that the image is formed of electromagnetic radiation passing through the filter, thereby removing the characteristic defect from the image and improving the contrast between the physical features and the background in the image.

In one exemplary embodiment of the invention the filter is moved linearly into position.

In another exemplary embodiment of the invention several available filters are mounted on a wheel and rotated into position.

Another aspect of the invention may be found in a circuit board or card on which is surface mounted a part that has been recognized in accordance with the method. Through use of the method, recognized physical features of the mounted part are placed in registration with contact pads of the board or card.

BRIEF DESCRIPTION OF THE DRAWINGS

Other aspects of the invention will become apparent upon perusal of the following detailed description when taken in conjunction with the appended drawing, wherein:

FIGURE 1 is a schematic elevational cross-section view of visualization, recognition and placement apparatus in accordance with the invention;

FIGURE 2 is a top view of illumination and reption parts of FIGURE 1, as viewed from the lines 2-2;

FIGURE 3 is a cross-section view of visualization, recognition, placement and linear filter deployment apparatus in accordance with the invention, with the filter retracted;

FIGURE 4 is a cross-section view with the filter deployed;

FIGURE 5 is a cross-section view of another embodiment of the invention, showing a rotational filter deployment apparatus; and

FIGURE 6 is a top view of the rotational filter deployment apparatus of FIGURE 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGURE 1 of the drawing, an embodiment of the present invention for visualization of parts having metallic objects against a dielectric or non-metallic poorly contrasting background, is explained in conjunction with a conventional computer vision system **10** recognizing a usually two dimensional Ball Grid Array (BGA) **12** of small high melt solder balls **14** carried by a ceramic dielectric substrate **16**.

BGA **12** is held by a gripper or manipulator **18** of a pick and place machine (not shown) over an upwardly looking camera **20** of computer vision system **10**. The camera **20** forms and provides an electronic image to computer vision system **10**, which system utilizes the electronic image to recognize and inspect the solder balls **14** of the BGA **12**, as to existence, size and spacing. If the BGA **12** passes inspection, the vision system **10** steers the translation and placement of BGA **12** by manipulator **18** on a circuit board or card **22**, with the recognized solder balls **14** of the BGA in registration with contact pads **24** of the board or card **22**.

As is conventional, prior to placement of the BGA **12** and other surface mount components on the circuit board or card **22** the contact pads **24** are coated with a eutectic solder paste, and after the placement of the BGA **12** and other surface mount components on circuit board or card **22**, heat is applied to card with placed BGA and other components to fuse the solder paste into fillets (not shown) firmly surface mounting the BGA to the circuit board or card.

In the poorest contrast situation when the solder balls **14** are silver colored and the substrate **16** is white

or light colored, the light box **26** is used to provide generally upwardly and inwardly directed polarized illumination **I** of BGA **12**, in conjunction with a polarization filter **28** in front of the lens **30** of camera **20**, in order to allow for proper visualization by camera **20**, and proper recognition by vision system **10** of solder balls **14**.

As shown in FIGURE 2, a preferred embodiment of light box **26** has a central aperture **32** through which camera **20** looks upward via polarization filter **28**, and four upwardly and outwardly inclined trapezoidal faces **34**, **36**, **38**, **40** of a frusto-pyramid, each face forming a separate source of polarized light. The faces **34**, **36**, **38**, and **40** comprise polarization filters **40**, **42**, **44**, and **46** over respective milk glass diffuser panels **50**, over LED arrays **52**.

With the direction of linear polarization passed by polarization filter **28** taken as 0°, polarization filters **40** and **44** are oriented to pass linear polarization directed at 90° and polarization filters **42** and **46** are oriented to pass linear polarization directed at 180°. The result is that the downwardly directed component of light from the four sources reflected from the solder balls **14** has a polarization at 90°, which is, or is nearly, orthogonal with the polarization direction that would be passed by polarization filter **28**. Therefore no light reflected by solder balls **14** reach the lens **30** of camera **20**.

On the other hand, the downwardly directed component of light reflected from the white or light colored substrate **16** is substantially uniformly distributed in polarization and a substantial amount of light reflected

downward from the substrate **16** passes through polarization filter **28** and reaches the lens **30** of camera **20**. As a result, in the electronic image formed by camera **20**, the solder balls **14** appear substantially black and the substrate **16** appears substantially white, providing good contrast for reliable recognition of solder balls **14**. This contrast producing effect is thought to be due to a preservation of polarization in reflection of electromagnetic radiation from shiny metal objects versus a the smearing of polarization in reflection of electromagnetic radiation from dielectric objects.

A printed circuit board assembly machine will inspect parts of different types during the assembly of a single circuit board. If some of the parts being inspected have a light colored substrate, while others have a black substrate, an additional problem arises. Because the effect of the linear polarizing filter **28** is to cause the solder balls **14** appear substantially black in the electronic image formed by camera **20**, the solder balls may not be easily recognized on parts having a black substrate, when viewed through such a filter. In this situation, it is desirable to deploy the filter **28** in front of the lens **30** of camera **20** when visualizing parts with a white substrate, and retract the filter when visualizing parts with a black substrate.

A similar problem arises when the circuit board assembly machine handles printed circuit boards or cards. Some circuit boards are manufactured with a fiberglass substrate, which is typically green in color. Such a substrate provides good contrast with the silver or gold colored fiducials used to register the parts installed on

the circuit board. However, other circuit boards or cards handled by the same assembly machine may have a white, or other light colored, ceramic substrate, which provides poor contrast with the metallic fiducials. The technique described above for deploying a filter when appropriate to achieve reliable recognition of solder balls on parts having either light colored or dark colored substrates can also be used to reliably recognize metallic fiducials on either light colored or dark colored printed circuit boards and cards.

The control system of a circuit board assembly machine typically utilizes a specification file for each type of item (printed circuit board, card or part) it handles. This file contains information on the characteristics of each type of item. Information from that file, such as the number and location of physical features (fiducials and contact pads on boards and cards, or contacts on parts), is provided to the computer vision system for the inspection process. In an assembly machine employing the techniques of the invention, the specification file would also contain information indicating whether a filter should be used when inspecting an item of that type and, for the embodiment shown in FIGURE 5, specifying which type of filter is to be used.

Referring now to FIGURE 3 of the drawing, an embodiment of the invention employing a linear filter deployment apparatus **60** is shown with the filter retracted. A filter **61** is attached by linkage **64** to linear actuator **65**. When energized by the circuit board assembly machine control system, the linear actuator **65** will adopt the configuration shown, with the filter

retracted from the optical axis of the camera **20**. When de-energized by the control system, the linear actuator **65** will adopt the configuration shown in FIGURE 4 of the drawing, with the linkage extended and the filter **61** deployed in front of the lens **30** of camera **20**.

For some types of linear actuators, the action of the actuator **65** will be the opposite of that described above: when the actuator **65** is energized, the filter **61** will be deployed and when the actuator **65** is de-energized, the filter **61** will be retracted. While the above description discusses the use of a linear actuator to deploy filter **61**, it should be understood that a solenoid could also be employed in an embodiment of the invention.

Filter **61** in FIGURES 3 and 4 could be the linear polarization filter **28** shown in FIGURE 1, employed in combination with linearly polarized illumination, as described above, to correct the visualization problem associated with metallic physical features on a light colored background. Or, filter **61** could be one of several other types of filter chosen to correct other characteristic problems, as will now be described. These other types of filters can be used to equal effectiveness with polarized or non-polarized illumination.

If the item being visualized has, for example, red physical features on a green background, filter **61** could be chosen to be a red color filter. Such a filter would pass the red light reflecting from the red physical features while blocking the green light reflecting from the background, causing the physical features to appear substantially white and the background to appear

substantially black in the image from a monochrome camera.

If camera **20** employs a charge coupled device (CCD) to form the electronic image, items that are especially reflective in the infrared spectrum may present a different characteristic visualization problem. Because a CCD is very sensitive to radiation in the infrared spectrum, the electronic image of such an item may be washed out, with both the physical features and the background of the item appearing as light gray objects in the image, preventing the computer vision system from being able to recognize the physical features on the item. For this type of item, filter **61** could be chosen to be an infrared filter, which blocks infrared radiation and passes visible light. Blocking the infrared radiation would allow the CCD to form an electronic image only from the visible light reflected from the item, resulting in better contrast between the physical features and background of the item in the filtered image.

If glare is characteristically encountered when visualizing certain items, the image produced by camera **20** will again be washed out. In these situations, filter **61** could be chosen to be a circular polarizing filter. Such a filter restricts the rotation component of the illumination reflected from the item, thereby reducing glare from the item and allowing correct recognition of the physical features on the item.

While the preceding discussion has described recognizing contacts on electronic parts or fiducials and contact pads on printed circuit boards and cards, it should be understood that the physical features being

recognized on other items may not be contacts or fiducials. For example, when a lens is to be mounted over a light emitting diode, the lens will be inspected for mounting features that allow it to be attached to the circuit board or card. Similarly, a circuit board or card may be inspected for the presence and accurate placement of thermoset adhesive glue dots, which serve to mount parts that are not soldered to the board.

If the items being handled by a circuit board assembly machine each exhibit a different characteristic problem, then one of several different filters must be deployed, depending on the item being inspected, to allow reliable recognition of the physical features of that item. An embodiment of the invention allowing one of several filters to be deployed is illustrated in FIGURE 5 of the drawing. A rotational filter deployment apparatus **70** is shown, which is a filter wheel **75** mounted on the shaft of stepper motor **76**. Also visible in FIGURE 5 are filters **61** and **63** mounted on the filter wheel **75** in registration with apertures **72** and **74**. In response to signals from the assembly machine control system, stepper motor **76** will rotate to a specified position, thereby deploying the appropriate filter for the part being visualized.

The rotational filter deployment apparatus **70** is shown in more detail in FIGURE 6. Filter wheel **75** can be seen to have, in this embodiment of the invention, four apertures **71**, **72**, **73**, and **74**. Apertures **72**, **73**, and **74** are covered by filters **61**, **62**, and **63**, respectively, while aperture **71** is not covered with a filter. The hub of filter wheel **75** is mounted to the shaft of stepper motor **76**. Lens **30** is seen through aperture **74**.

While motor **76** is described above as a stepper motor, it should be understood that servo motors could also be used in an embodiment of the invention to position filter wheel **75** in response to signals from the assembly machine control system.

While FIGURES 3, 4 and 5 show embodiments of the invention being used for visualization of a BGA package, it should be appreciated that the techniques of the invention can be used to improve visualization of other types of packages and of printed circuit boards and cards.

While the embodiments discussed above show only a single filter deployment apparatus in use, it should be understood that, in yet another embodiment of the invention, multiple filters could be deployed together by multiple filter deployment apparatuses, to improve visualization of items that present multiple characteristic problems.

It should now be appreciated that the objects of the invention have been satisfied. While the invention has been described in particular detail, it should also be appreciated that numerous modifications are possible within the intended spirit and scope of the invention. In interpreting the appended claims it should be understood that:

a) the word "comprising" does not exclude the presence of other elements or steps than those listed in a claim;

b) the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements.

c) any reference signs in the claims do not limit their scope; and

d) several "means" may be represented by the same item of hardware or software implemented structure or function.